ACOUSTIC MEASUREMENTS OF SAND RIPPLE PROFILE EVOLUTION UNDER CONTROLLED WAVE CONDITIONS

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Recent developments in high frequency acoustic backscatter system (ABS) have made possible the development of an acoustic sand ripple profiling system capable of in-situ measurement of sand ripple and microtopography profiles over a 2-3 m length of sea bed. The system has previously been tested under laboratory and estuarine conditions and now, for the first time, under wave conditions. Parameters related to the sea bed roughness have a direct bearing on the re-suspension of sediment and will therefore be of importance to the production of sediment models, which currently rely on a single bed roughness parameter to encompass these effects The prototype sand ripple profiling system was mounted on a platform, STABLE II, approximately 1.2 m above a sand bed in the Delta Flume large scale facility at the De Voorst site of Delft Hydraulics in the Netherlands. The flume is approximately 5 m wide, 7 m deep and 230 m long. A 0.5 m deep sand bed was covered by 4.5 m of water during a six week series of experiments. The size of the Delta Flume and the range of wave conditions that can be produced within it allow instrument testing to be carried out in conditions that are equivalent to those found in nature. Both regular and irregular waves of period 5 seconds and height ranging from 0.5 m - 1.25 m were used over two separate sand beds with median grain diameters of 0.162 mm and 0.329 mm. Asymmetric waves of periods 4 and 6 seconds with waveheight of 1 m were also used. Profile measurements were taken at approximately 30 second intervals to produce time series of ripple profiles over the full range of wave conditions. Examples of data collected by the sand ripple profiler during these experiments are presented, showing the sand ripple profiles and their evolution under a variety of wave conditions with the two sand beds.

1. INTRODUCTION

The application of multifrequency acoustic backscattering to the measurement of nearbed suspended sediment dynamics is a technique that is increasingly becoming accepted by sedimentologists. These systems provide detailed information on the suspension, but limited data on the bed. Since it is the interactions between the flow dynamics and the bed form that lead to the entrainment of sediments into suspension, measurements of the bed features are an essential component in developing a framework for understanding suspension processes. Most theoretical predictions of suspended sediment profiles require a knowledge of the bed form, for example, is the bed plane or rippled, and if the latter, what are the amplitude and wavelength of the ripples? To date, the input of bed form parameters has been problematic because of the difficulty of obtaining such measurements.

A variety of approaches to this problem have been taken by researchers in the past. Direct measurement can be carried out under static conditions using mechanical methods either by divers, or automatically in laboratory conditions. Optical methods have also been used, for instance Wilkinson [1], and Crawford and Hay [2], however these are limited by the ambient visibility. Acoustic techniques are less sensitive to low visibility, and a variety of approaches have been taken by various groups, such as Greenwood et al [3], Hay and Wilson [4] and Vincent and Osborne [5].

The Sand Ripple Profiler (SRP) used in the work described here was based upon a pipe profiling sonar developed by Marine Electronics Ltd. [6], and has previously been tested over a known surface (Bell & Thorne [7]) and under estuarine conditions (Bell & Thorne [8]). The data presented here were recorded during experiments conducted over the summer of 1997 at the Delta Flume large scale facility at the De Voorst site of Delft Hydraulics in The Netherlands (Williams et al, [9]). The SRP was mounted on the STABLE II instrument tripod, which was lowered into the flume onto a 0.5 m deep sand bed. A variety of wave conditions was produced by the flume during which the SRP recorded the development and evolution of sand ripples. A selection of the processed data from that experiment are presented here together with one of the first images produced by a new sector scanning sonar - the Sand Ripple Imager (SRI).

2. DEPLOYMENT IN THE DELTA FLUME

During the summer of 1997, tests were carried out on the STABLE II instrument package in the Delta Flume at the De Voorst site of Delft Hydraulics in The Netherlands as part of the EU 'Access to Large Scale Facilities' program. This provided an ideal opportunity to test the capabilities of the SRP under a range of controlled wave conditions. The Delta Flume is 230 m long, 7 m wide and is filled to a depth of 5 m. At one end, there is a wave generator, and at the other, a concrete beach. A series of tests were performed during a six week period over two separate sand beds, approximately 30 m long, 5 m wide and 0.5 m deep. The medium grainsize sand bed had a D_{50} = 0.329 mm, and the fine

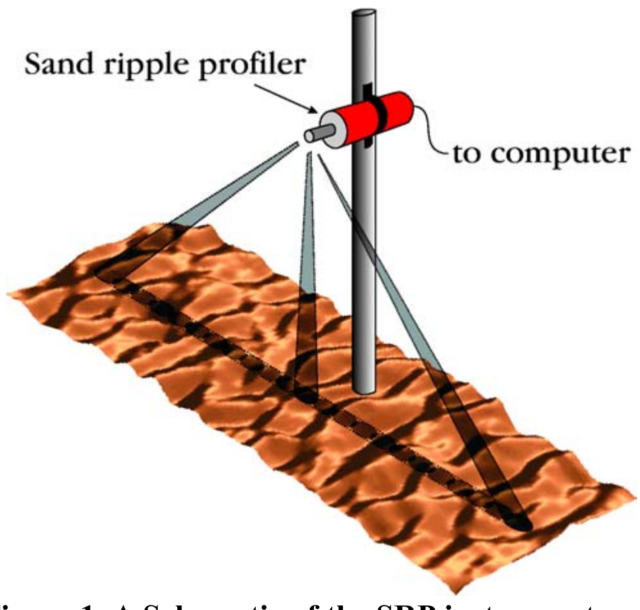

Figure 1. A Schematic of the SRP instrument.

grainsize sand bed had a D_{50} = 0.162 mm. The flume was filled to an overall depth of 5 m, giving 4.5 m of water above the sand bed. Ranges of different wave conditions were generated within the flume, both regular and irregular up to 1.25 m waveheight, with periods of up to 6 seconds.

The STABLE II instrument tripod (Humphery and Moores [10]) has a diameter of approximately 3 m and an overall height of approximately 1.8 m. The standard instrument suite mounted on STABLE consisted of three Valeport annular electromagnetic current meters, a triple frequency acoustic backscatter system, pressure and temperature sensors, compass and inclinometer. In addition to this standard suite, a pumped sampling system, a high resolution coherent Doppler current profiler, a Sontek ADV and the sand ripple profiler were also mounted on the rig.

The SRP was clamped to the underside of the frame, at a nominal height of 1.2 m above the seabed. This allowed a line of the seabed beneath STABLE to be scanned approximately 1.5 m in front and behind the SRP, enabling details of the ripples both beneath and in front of the STABLE rig to be resolved. A single scan of this line took approximately 30 seconds to complete, with consecutive scans beginning immediately upon completion of the previous one. The incoming profile data were displayed in real time on the control PC, allowing the evolution of the bed form to be observed during the experiments, and an assessment of the time taken for the bed form to stabilise following a change in wave conditions to be made. The data were post processed using a bed recognition algorithm (Bell & Thorne [6]) to produce the co-ordinates of the sea bed for each scan.

At convenient moments when the waves were switched off, an acoustic Sand Ripple Imager (SRI) was lowered into the flume to provide images of the sand bed. The SRI is a similar system to the SRP, but with a small sidescan transducer instead of a pencil beam. In this case the analogue signal was digitised by a high speed analogue to digital converter card in the host PC on the surface.

On three occasions while the waves were switched off, a mechanical profiler integrated onto one of the large moving platform at the Delta Flume was used to provide profiles of the entire sand bed at 25 cm intervals across the flume and 1 cm intervals along the flume.

3. RESULTS

The Sand Ripple Profiler was run during all of the 20-minute test periods for STABLE throughout the six-week experimental phase. In addition to these measurements, the instrument was left running for a significant proportion of each day to observe the evolution of the sand bed over longer timescales. The backscatter data produced by the SRP was post-processed to yield the ripple profile information using the analysis described above.

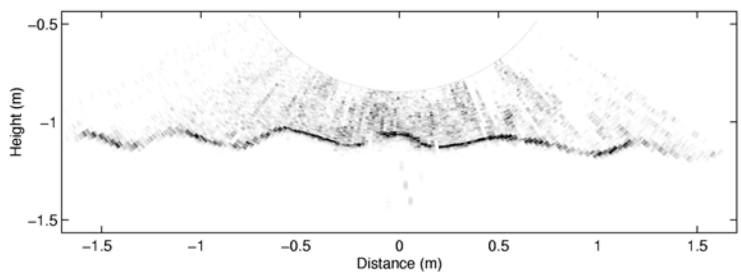

Figure 2. A backscatter image showing sand ripples and significant levels of suspended sediment.

During the tests, there were significant levels of suspended sediment visible on the SRP images, in many instances exceeding the signal from the bed itself. An example of such an image is shown in Figure 2, recorded during 1.25 m, 5 sec regular waves.

In most cases the analysis that has been developed succeeded in distinguishing the bed echo from the suspended sediment, providing a true representation of the bed profile. In cases where the bed echo was completely masked by the suspended sediment, a routine was applied which detected anomalous points and replaced them with a best guess based on the values from adjacent space and time bins. For comparison, an image with little suspended sediment is shown in Figure 3, recorded during significant waveheight Hs=1.25 m, peak period Tp=5 sec irregular waves.

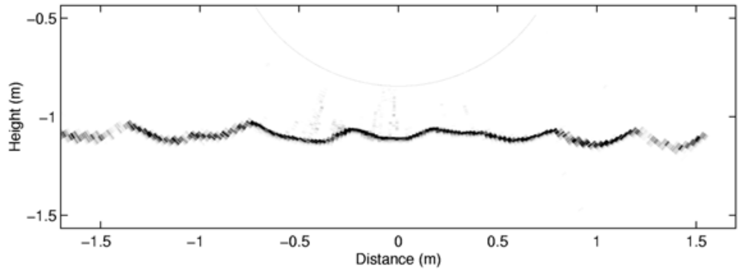

Figure 3. A backscatter image showing sand ripples and minimal levels of suspended sediment.

Eight sets of processed data are shown in Figure 4. These data illustrate the sand ripples encountered over both fine and medium sand beds, and under regular and irregular wave conditions of period 5 seconds and heights of 0.5 m and 1 m.

The SRI provided additional information on the overall form of the sand ripples by providing images of the bed covering a 5 m radius. An example of such an image is shown in Figure 5. This image was recorded after the STABLE tripod had been lifted following a series of 5 second, 1 m regular waves, the same conditions that produced the data shown in Figure 2. The sand ripples are clearly visible on the image, together with the footprints from the STABLE tripod.

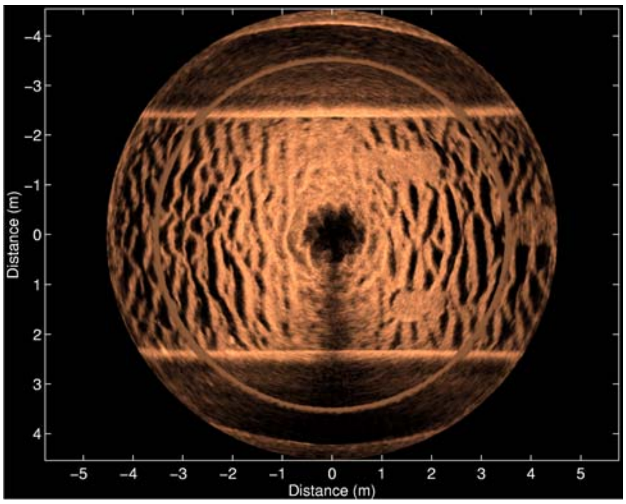

Figure 5. An SRI image of the sand bed showing sand ripples and the footprints of the STABLE tripod.

4. CONCLUSIONS

The SRP system described here has been shown to allow the in-situ profiling of seabed features even under conditions of high suspended sediment concentration. A single profile of the bed takes approximately 30 seconds to complete, although future versions of the system are expected to reduce this time to less than 5 seconds. The system appears to underestimate the heights of the extremes of the sand ripples due to the finite width of the acoustic beam. Despite this, the accuracy is believed to be to within 5 mm of the true ripple profiles. Future publications will include a more rigorous investigation of this aspect the system.

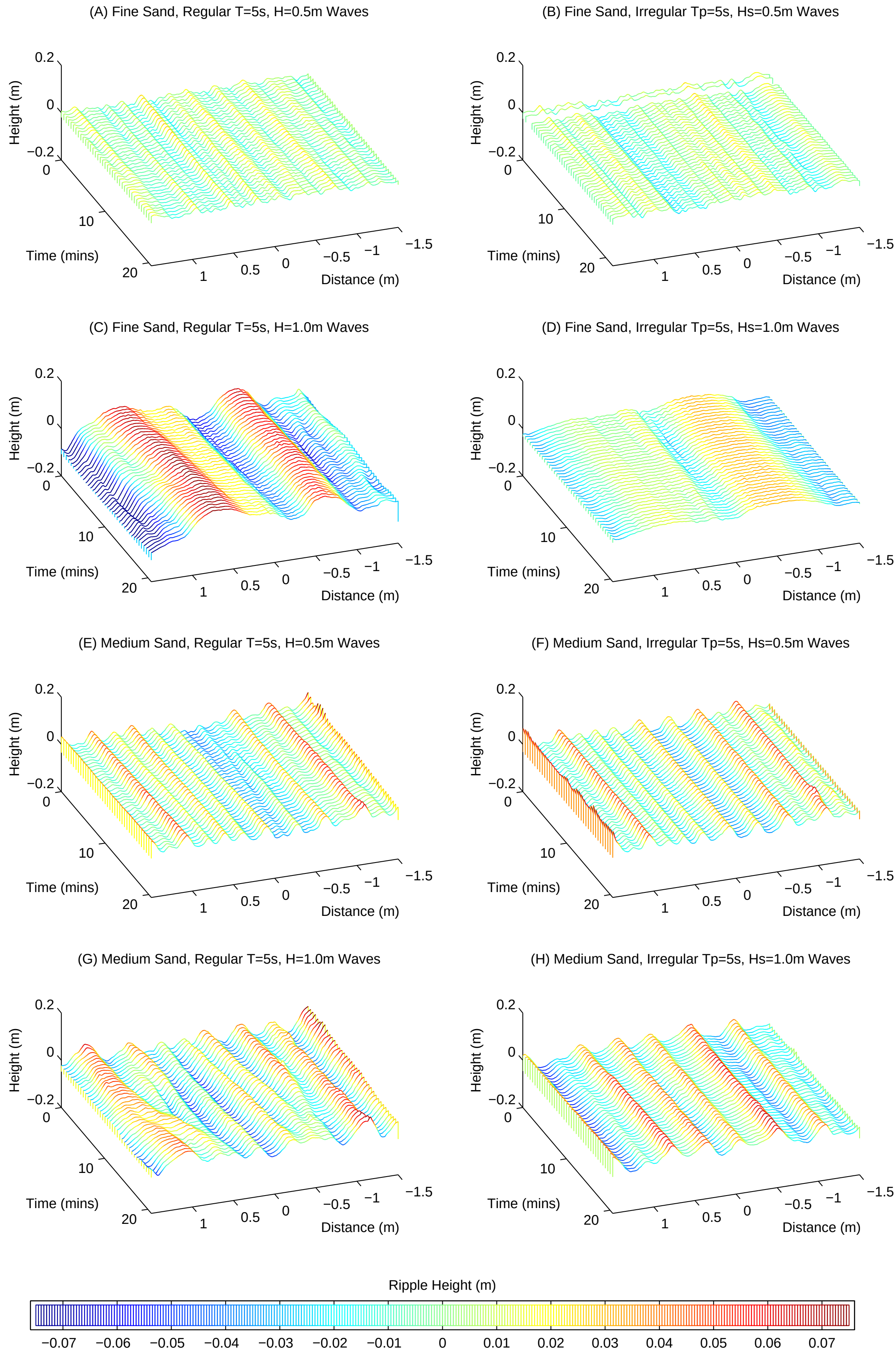

Figure 4. A series of sand ripple profiles for fine and medium sand under a variety of wave conditions.

The data recorded during the Delta Flume experiment are believed to be the most extensive measurements of this type yet performed under a range of wave conditions from 0.3 m up to 1.25 m waves with periods of 5 and 6 seconds. Both regular and irregular wave conditions were used over two separate sand beds of median grain diameters D_{50} = 0.329 mm and 0.162 mm. Examples of the data produced are presented, illustrating the different ripples and their evolution, formed under the various conditions. The SRI instrument has been used for the first time to visualise seabed features, and complements the SRP by providing additional information regarding ripple orientation and regularity over an area of radius at least 5 m.

5. ACKNOWLEDGEMENTS

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